FORTUNE
May 1946

THE PHYSICS OF THE BOMB

by **Dr. A. K. Solomon**

In March, FORTUNE printed an article by Dr. Lise Meitner, "The Nature of the Atom," reviewing our growing knowledge of the structure of matter.

The atom, as seen in that article, is an infinitely tiny unit of matter, made up of three basic particles: *protons* (positive charge) and *neutrons* (no charge) bound together in a massive nucleus at the center, with *electrons* (negative charge) whirling around the core in distant orbits, like minuscule planets around a sun. The basic atoms of matter build up in mathematical order from hydrogen (one proton, one electron) to uranium (92 protons, 142 to 146 neutrons, 92 electrons). Atoms of the same element with different numbers of neutrons are called *isotopes*. The sum of protons and neutrons is an atom's mass number—for one uranium isotope it's 92 + 146, or U-238.

For over twenty-five years physicists have been chipping at atomic nuclei with subatomic particles fired at high speed, changing one element to another, transmuting most elements on a small scale with some small releases of energy. With the fission of uranium by neutrons in 1939, however, man for the first time split an atom almost in half, releasing energy of an order never before originated on earth. Dr. Meitner's article carried the story this far.

Dr. A. K. Solomon, research fellow at Harvard in physics and chemistry, takes up the account from fission to the bomb. He is a thirty-three-year-old American physicist who worked with the British on radar for most of the war and is now associated with the U.S. National Research Council. In 1940 he published a book, called *Why Smash Atoms?* later reprinted in the British Penguin series and now reissued by Harvard in a revised edition.—*The Editors.*

The atomic bomb is a technological development of the highest political significance. Nonetheless, it is a byproduct of our attempts to learn the laws of nature. This byproduct is not the first, nor will it be the last, to emerge as a result of untrammeled scientific research.

Modern nuclear physics may be said to have sprung from the triple scientific discoveries that illumined the years 1895 to 1897. In 1895 Röntgen in Germany discovered the X-ray; in 1896 Becquerel in France discovered radioactivity; in 1897 Thomson in England identified the electron. The work that began in these European countries has been extended and carried on all over the world.

From these beginnings followed the manifold investigations into the atomic nucleus leading up to the discovery in 1939, almost simultaneously in Denmark, France, and the U.S., of uranium fission. A further investigation of this phenomenon, the scientific inheritance of all the countries of the world, has led the U.S. to the development of the atomic bomb. There is no more reason now than there was in 1919 when Rutherford first transmuted matter to believe that the contemporary discovery is the pinnacle of scientific achievement.

The Sun: $E = mc^2$

The sun is the most familiar atomic-power plant known. It converts more than four million tons of mass into energy per second (yet has lost only about .01 per cent of its total mass since earth's formation), operating on the Einstein equation—energy equals mass times the square of the velocity of light.

Hydrogen makes it go

In the sun's interior (20,000,000° C.), four single-proton hydrogen atoms are welded in a cycle of six complex reactions (shown as one) to form one atom of helium. The loss of mass in this coming together of matter is small, but "burns" out 25.6 million electron volts of energy per cycle.

The Bomb: $E = mc^2$

The atomic bomb, working on the same Einstein equation, converts approximately one-thirtieth of an ounce of mass into energy in a fraction of a second. It releases a blast of radiant heat and energy comparable to one infinitesimal licking flame from the corona of the sun.

Uranium makes it go

The bomb goes to the other end of the table of elements to split the heavy uranium atom into two lighter ones (instead of putting light atoms together)

SLOW, FAST, AND FREE NEUTRONS

Hard upon the heels of the first report of the fission of uranium came scores of scientific papers and new discoveries. Perhaps the most significant was the discovery of the slow-neutron effect. Uranium fission could be produced not only by bombardment with normal, fast neutrons, but with even greater efficiency by slow neutrons—neutrons whose tremendous speeds had been slowed down. The explanation for this was first put forward theoretically by Niels Bohr, in collaboration with a former student. Early in 1939 they suggested that the slow-neutron effect was caused by a rare isotope of uranium—uranium-235, present in ordinary uranium ores only to .7 per cent. In 1940 a small amount of this isotope was separated in a mass spectrograph. Experiments confirmed the theory that U-235 was more readily fissionable by slow neutrons than fast.

In 1937, before the discovery of uranium fission, Hahn, Meitner, and Strassmann had shown that bombardment of uranium with neutrons produced a radioactive isotope of U-239, which gave off electrons and had half-life of twenty-three minutes. Loss of an electron meant that the atomic number had risen from 92 to 93, and a new element had been formed.* A careful series of observations in the late spring of 1940 confirmed the existence of this new element, now called neptunium, and showed that it was also radioactive. Neptunium itself decayed with a half-life of 2.3 days and emitted still another electron to form a second new element with an atomic number of 94, now called plutonium. This new element was expected to disintegrate with the emission of an alpha particle. The alpha particle has since been found; the half-life of plutonium is so long that during a human lifetime there is no appreciable loss by radioactive decay.

One further important observation was published. In addition to the highly energetic heavy fragments thrown off in fission, neutrons were emitted. The number was indeterminate, varying from about one to three per fission. At first no one could definitely state whether the neutrons were emitted at the instant of

M. Leibowitz

fission, or later. But this was not the most arresting problem. The mere fact that a single bombarding neutron could liberate great energy and at the same time produce at least one new neutron lent substance for the first time to the Sunday supplement's favorite stories about atomic energy. Hitherto the liberated energy in the transmutation of a single atom had been great, though puny in comparison with fission's 200 million electron volts. But atoms are very small, and many of the bombarding particles passed right through without penetrating a nucleus; only an infinitesimal number of nuclei were ever disintegrated. Consequently, the total amount of energy produced was woefully small. The prospect of new neutrons produced by the bombarding neutron changed that reasoning. For if one neutron produced, say, two neutrons, and each of these produced two more, fission would provide its own source of particles—and hence establish a chain reaction.

Broadly, this was the state of our published knowledge in the summer of 1940. Uranium fission had been discovered. Theory had predicted, and experiment confirmed, that the isotope U-235 was peculiarly sensitive to fission, so much so that it required only slow neutrons to do the trick. Two transuranic elements, neptunium and plutonium, had been further investigated, and their position in the periodic table established with reasonable certainty. Finally, it had been proved that for every neutron lost in the fission process, at least one additional neutron was found. Atomic energy was no longer impossible.

EXPERIMENTS IN CHAIN REACTIONS

The realization of the potentialities of atomic power did not lag far behind these discoveries. In March, 1939, Enrico Fermi discussed with the Navy the use of the atom as a weapon of war. The Navy expressed interest and asked to be kept informed. In the fall a second proposal was made, this time to President Roosevelt, supported by a letter from Einstein. The President set up a committee, and the government began to take an active interest. The first real allocation came in November, 1940—$40,000 for a year's work, on a contract given to Columbia University. It seems peculiarly significant that the subject was first broached to the U.S. Government by Fermi, an Italian who had fled from fascism. From the historical account of those early days, it is apparent that much of the driving force in this development came from Europeans now resident in this country.

Before any progress could be made in evaluating the speculations of the scientific world, it was necessary to back them up with sound experimental fact. The first thing to prove was that a chain reaction would work.

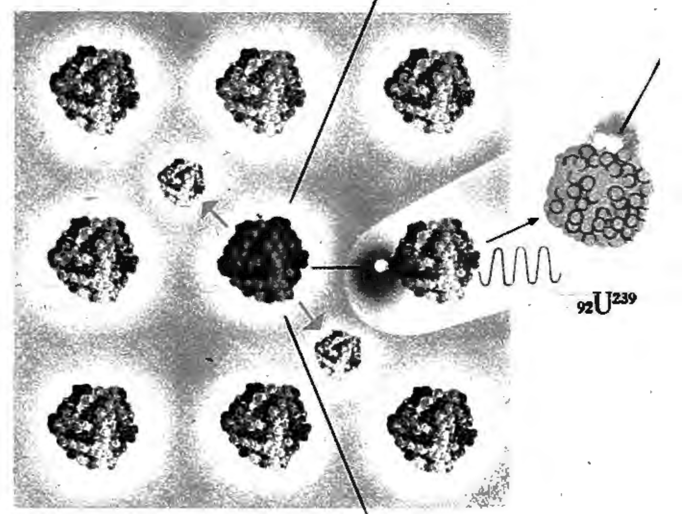
The problem was whether the additional neutrons produced would themselves be effective in disintegrating further nuclei. This problem is not easy. There are a number of competing fates that await the neutron wandering through a lump of uranium. First, if the lump is small, the neutron may escape through the surface into the atmosphere. This escape can be minimized only by making the amount of uranium very large. Second, the neutron may be captured by absorption into the nuclei of impurities in the uranium. Some impurities have a probability of neutron capture vastly in excess of uranium. Third, the neutron may be captured by uranium in a way that does not produce fission. It is this process that occurs when a neutron is captured by U-238 to produce U-239, leading to the end product, plutonium. Only a neutron not lost to any of these processes is available to cause fission of another uranium atom.

THE ATOMIC PRODUCTION LINE

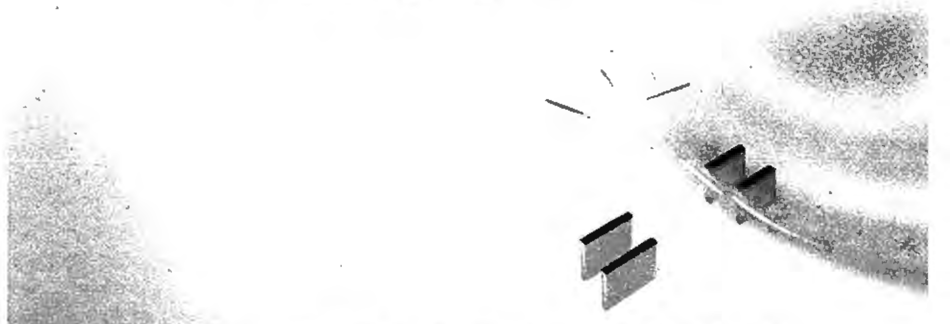
In a lump of plain uranium metal two major isotopes are distributed in these proportions in a speck the size of a dot over an "i":

2,532,000 trillion atoms of U-238 (99.28%)
18,000 trillion atoms of U-235 (.71%)

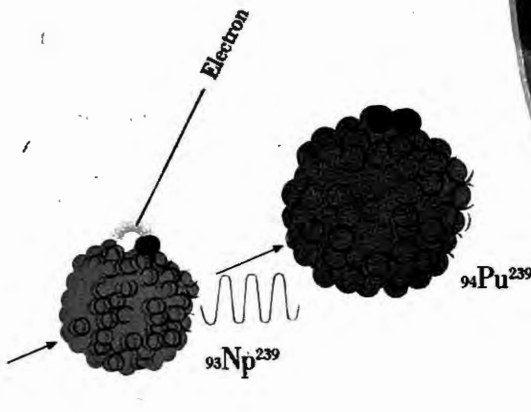
In the tiny cross section below, U-238 nuclei are shown in yellow, U-235 in red. Both are fissionable, but U-235 more readily than U-238, and to an even higher degree by slow neutrons than by fast. U-235 is so fissionable that it often splits spontaneously or on impact from stray neutrons from the atmosphere. But no explosions occur in natural uranium because no chain reaction can get started. U-235 splits up and releases free neutrons. But these may escape into space, be captured by impurities, or whizz into a U-238 nucleus to form U-239, which turns in two brief radioactive steps into plutonium-239 (a new element even more fissionable than U-235).

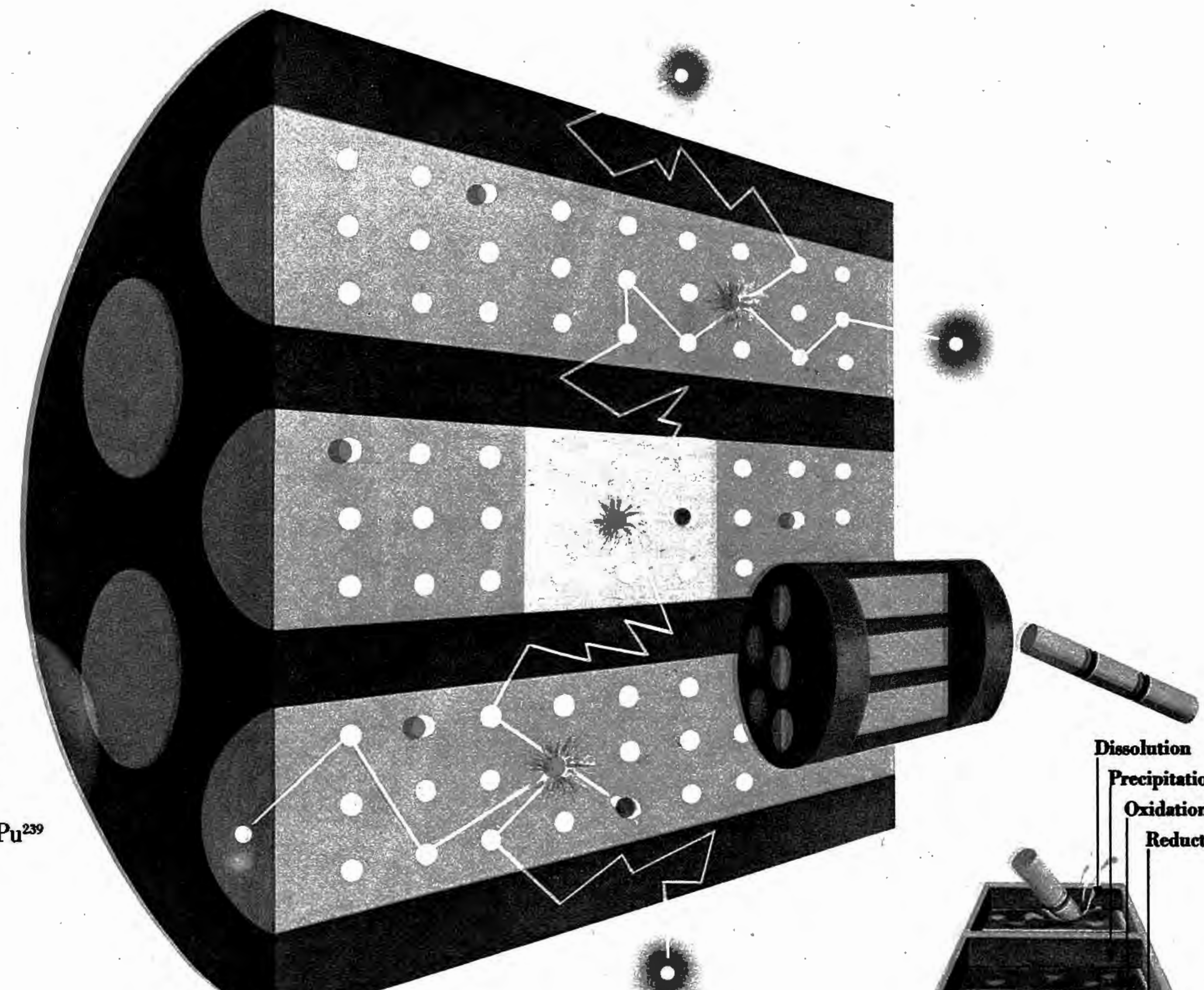


Only rarely does one of these neutrons find another U-235 to split. If the physicists could separate U-235 out of the lump or get enough plutonium deposited in it for separation, pure explosive products would result. Neither had ever been done. So they set out to work both sides of the street.



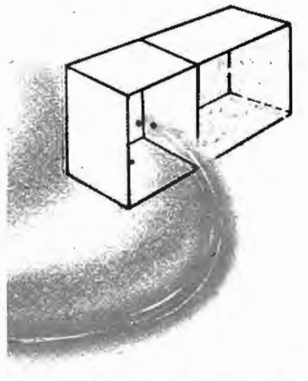
Electromagnetic Process: **A uranium salt is ionized and a beam of ions is shot into a large magnetic field, where their paths are immediately curved in a semicircle. The lighter ionized atoms of**



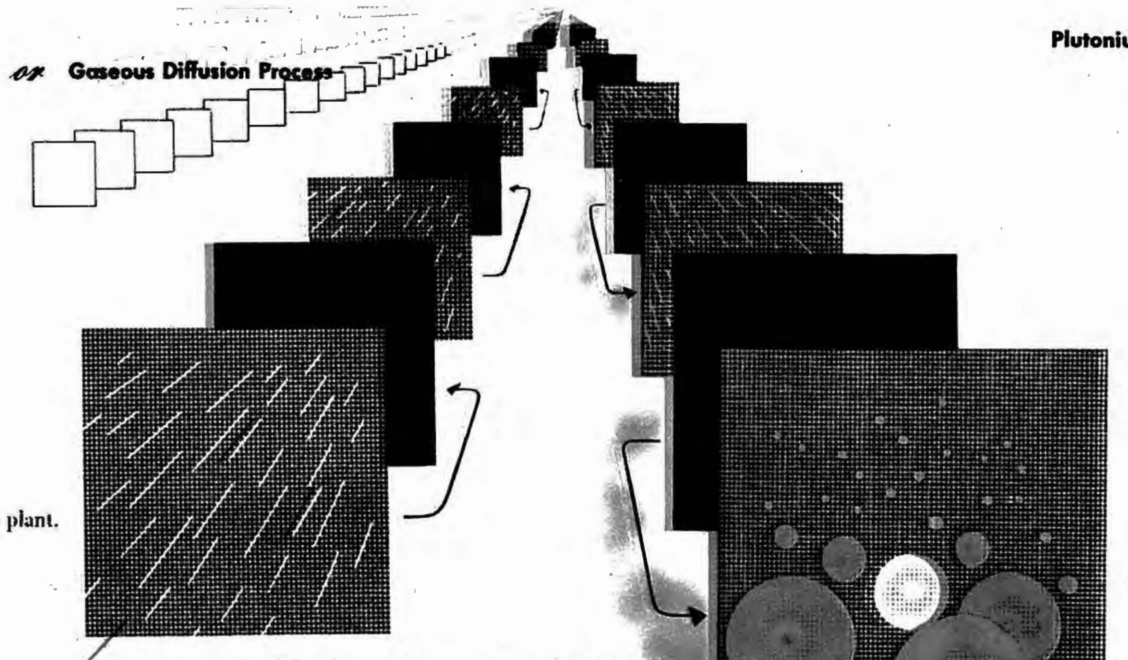


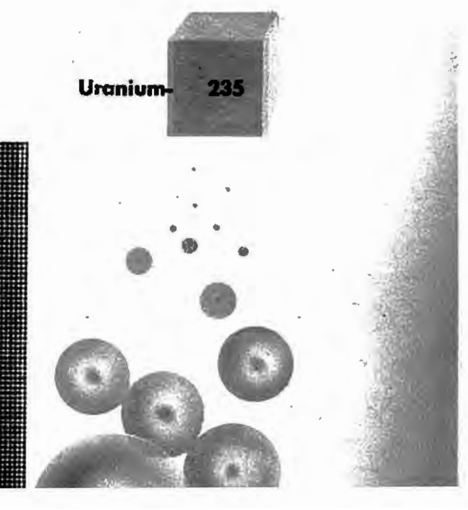
Plutonium: To get plutonium, the pile schematized above was devised. Cylinders of pure uranium slip into blocks of pure graphite and the reaction (light area) now goes to work. U-235 splits, releasing neutrons — one of them joining a U-238 to form plutonium (green). But the escaping neutrons go through the graphite, are slowed down by collision with carbon atoms, penetrate the other cans of uranium, carom off U-238's at low speed, and finally hit and split other U-235's to release more neutrons and form more plutonium. This sets going in the trillions of atoms a controlled chain reaction. Upon it was built the great Hanford plant on the Columbia River, generating as a waste byproduct of uranium fission energy about equal to the output of Boulder Dam. Uranium cans are fed through the piles, then go through remote-control chemical processes that separate the pure plutonium metal.

Uranium: **Electromagnetic Process** *or* **Gaseous Diffusion Process**



Both processes were used in the Oak Ridge plant.

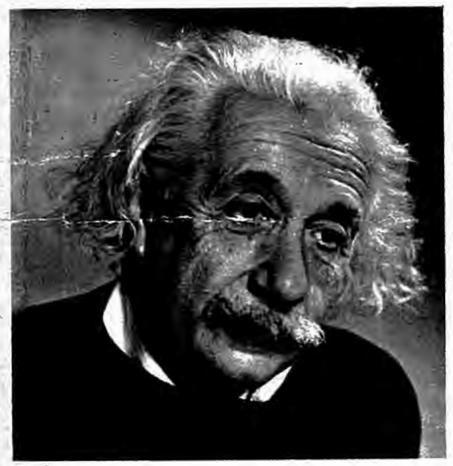




A uranium gas is diffused another stage and through

Slow neutrons—the most efficacious in bombarding U-235—were used in the first serious attempt to produce a chain reaction. Slow neutrons can be produced only indirectly. When a neutron hits any nucleus, its energy is divided between the colliding particles in inverse proportion to their mass. If it hits a light nucleus, like hydrogen, with a mass almost equal to the neutron, the energy is shared equally between the two. Consequently, when a beam of neutrons is shot into material containing much hydrogen, like paraffin or water, the neutron is soon slowed down by successive collisions until it can lose no more energy. Heavier elements than hydrogen can also serve as slowing-down elements, called moderators. To be effective, a moderator should not itself absorb neutrons from the limited supply. Since hydrogen could absorb neutrons to produce heavy hydrogen, the other light elements were closely scrutinized. Carbon was finally chosen as moderator because, in addition to being quite nonabsorbent, it alone could be produced in pure and large enough quantities in a reasonable time.

Experiments in mixing carbon with uranium soon showed that a lattice arrangement—alternating blocks of carbon and lumps of uranium—would be better than a homogeneous mass. The reasoning was this. In fission, fast neutrons are released. For greatest effectiveness in further fission, they must be slowed down. But before they reach a slow enough speed to be effective in causing fission in U-235, they pass through a dangerous region—a speed corresponding to an energy of about twenty-five electron volts. U-238 has a very high probability of capturing twenty-five-volt neutrons to form U-239. By carefully spacing the uranium in a lattice, this danger could be made very small. For if a neutron once escaped from its originating lump of uranium, it would have to travel far enough through the carbon moderator to slow it down well below the twenty-five electron volt region before it reached the next lump of uranium. Thus the neutron loss to capture by U-238 could be reduced, and the number of free neutrons available to cause fission would be enhanced.



E = mc²

With the right moderator, with adequate purity of materials, and with a lattice structure, the chance of neutron capture by nonfission processes was certainly minimized. But there still remained the possibility of loss to the surrounding atmosphere. For any given surface area a sphere has the greatest volume. Since neutrons are produced throughout the volume of the material, and since they can be lost only through the surface, the best shape for a lattice—or pile, as these experimental lattices came to be called—was spherical.

With the shape determined, size became important. Enough neutrons had to be produced so that the number lost to the atmosphere would be negligible. This condition immediately set a lower limit to the size of the experiment. Once all conditions inside the pile are adjusted to their best value, more neutrons can be produced only by an increase in size. And for given conditions inside, a certain critical size must be exceeded before the chain reaction can go. If the pile is smaller than the critical size, the number of neutrons lost to the outside makes the reaction impossible. As soon as the pile exceeds that size, a chain reaction is possible. The reaction needs no detonator since there rays, by the secondary effects from normal radioactive disintegration of uranium, or by spontaneous fission. Such were the basic factors in the early experiments.

POWER FROM THE NUCLEUS

All during 1941 experiments were carried out in laboratories throughout the country. In July at Columbia University the first lattice structure of graphite and uranium was set up. This pile was a cube about eight feet on each side. It contained approximately seven tons of a commercial grade of uranium oxide.

The best way to describe the operating principle of a pile is to characterize it by its multiplication factor, k. The necessary condition for a chain reaction is that each bombarding neutron produces slightly more than one new neutron—and k is the multiplication factor for the impinging neutron. If throughout the whole pile, one new neutron is produced per bombarding neutron, k is 1.0. If, on the average, only one-half a neutron is produced, k is 0.5; if two are produced, k is 2.0. The critical condition for a chain reaction is that k be at least unity. This is an exact way of stating that the reaction will proceed only if, after subtracting all the neutrons that are lost to the competing reactions, one new neutron is produced by each bombarding neutron. In the first lattice at Columbia, because of the impurity of the materials, this condition was not met and the reaction would not go.

In January, 1942, much of this experimental work was concentrated in the Metallurgical Laboratory at the University of Chicago. One of the immediate objectives was to set up a natural uranium pile of sufficient size and purity to make the chain reaction work.

Pure materials were difficult and slow to get in quantity, but physicists were not idle while stocks were accumulating. In one set of experiments they investigated the emission of delayed neutrons. It had been observed, and in fact published, that a small percentage of neutrons were emitted after fission was over. Investigation showed that this fraction was about 1 per cent. Of this 1 per cent, some were emitted only a few seconds after fission, while a few stragglers delayed as long as a minute.

The importance of delayed neutrons was that they provided a means of controlling the chain reaction. The value of k could always be made smaller by the introduction of neutron-absorbing materials, such as cadmium, into the pile. Consequently cadmium rods were inserted in the pile whenever it was necessary to suck neutrons out. Then k could be set up at a value so that, with the rods in place and neutrons blocked out, the chain reaction would be stopped. With rods out and the neutrons allowed to pass, k would be slightly greater than unity and the reaction would go ahead. The delayed neutron contribution gave a period of grace, lasting up to a minute, in which the reaction could be controlled if it showed any signs of being too active. In practice, a cadmium rod, with its depth of penetration into the pile governed automatically, provided safe and effective operation at any specified power level.

In November, 1942, construction of a new pile began in the now famous squash court under the West Stands of Stagg Field. Purified material was at hand, and calculation indicated that a k several per cent greater than unity should be realized. There still was not enough pure uranium to do the whole job, and the lattice was padded with uranium oxide. The pure metal was reserved for the center, where neutron density was highest.

other layer included lumps of uranium at the corners of squares. As new layers were added, holes were left for the cadmium rods and recording instruments. Each day that the pile grew, measurements were taken to check its performance against calculations. For safety the cadmium rods, normally in the retard position, were removed only once a day for these measurements. "This was fortunate," says the official report, "since the approach to critical condition was found to occur at an earlier stage of assembly than had been anticipated." Only three-quarters of the pile was up when critical size was reached. As a result the final structure, containing about six tons of pure uranium, looked less like a sphere than a gigantic doorknob.

On December 2, 1942, the controls were adjusted and the pile allowed to operate. It produced energy—one-half of a watt. Here was the first proof that the calculations and months of work were justified. Here was a chain reaction that produced energy from the atomic nucleus. This magnificent achievement is not to be measured by the amount of energy produced; the achievement is that on December 2, 1942, man first showed that nuclear power could be tapped and tamed.

THE SEPARATION OF U-235

Because of the urgency of war, there was no time to complete one experiment before launching another. Many possible processes had to be explored simultaneously, as the greatest precaution lest the enemy arrive at the answer before us. There was reason to believe that he was working on the same problem.

A prerequisite for any bomb at all was a supply of ready materials. All during work on chain reactions at Chicago, others were busy with the problem of separating U-235. This isotope, so particularly suited for fission, would clearly be of great use either for the construction of smaller piles to give atomic power or for construction of the bomb itself.

In the exciting days that followed the realization of the importance of U-235, many efforts were made to separate it from the much more abundant U-238. Such a separation cannot be carried out by simple chemical means because chemically all isotopes behave almost identically. Many ingenious schemes were proposed, but only two finally went into major production. Neither of these depended on novel principles, and hence the danger of large unexpected difficulties was minimized.

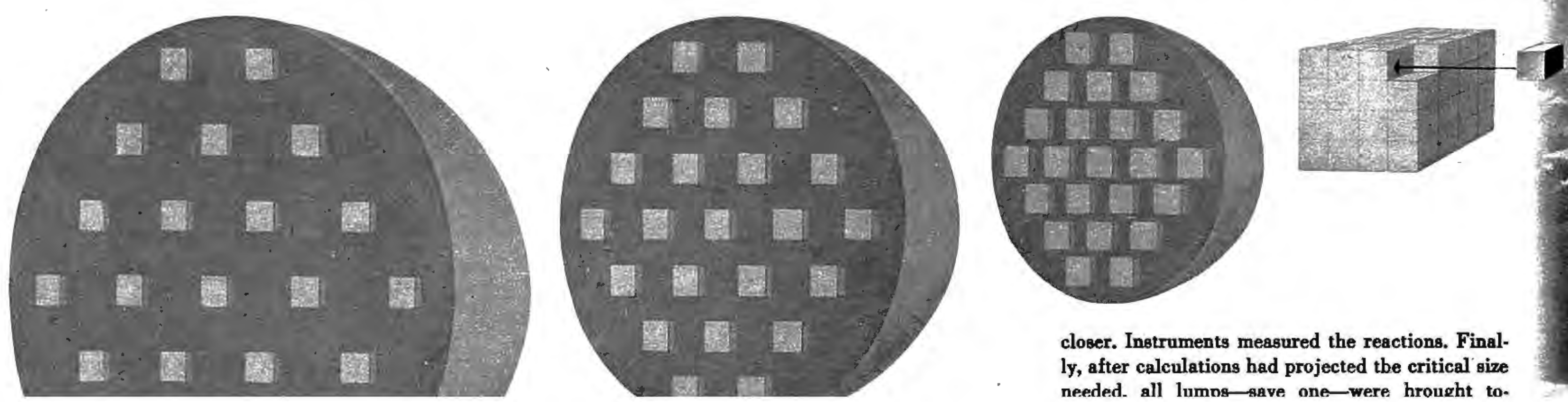
The first of these schemes, gaseous diffusion, was originally suggested for separation of gases in 1896. This plan depends on minute differences in the velocity of individual gas molecules. All the molecules in a gas are constantly in motion. At any given temperature, molecules of lighter gases travel faster than those of heavier ones. Between isotopes of a single gas, the difference in average speed is very small because it depends on the square root of the molecular weight. The gas used for U-235 separation was uranium hexafluoride, with a molecular weight of 349 for U-235, and 352 for U-238. If uranium hexafluoride gas is forced through a porous barrier, which it passes with some difficulty, the faster molecules will get through sooner. But the difference in speed is so small that the isotope separation through a single barrier is very slight indeed, and it is necessary to repeat the process many times through many stages.

Translation of this scheme into engineering reality required a tremendous plant, much ingenuity, and great patience. To supervise the atomic-bomb project, the Army in 1942 activated a new engineering district, called Manhattan District. Major General Leslie R. Groves, selected to head it, inspected and approved a seventy-square-mile site at Clinton (later known as Oak Ridge) in the Tennessee Valley. This vast Tennessee enterprise was called the Clinton Engineer Works.

Work was begun on the gaseous-diffusion plant in the summer of 1943. The many stages necessary to achieve any appreciable separation of the isotopes demanded a huge plant to produce U-235 in the amounts required. The job was not made easier by conditions at the site itself. Clinton Engineer Works was remarkable for its "seas of mud, clouds of dust, and general turmoil." However, by the summer of 1945, the plant was in operation.

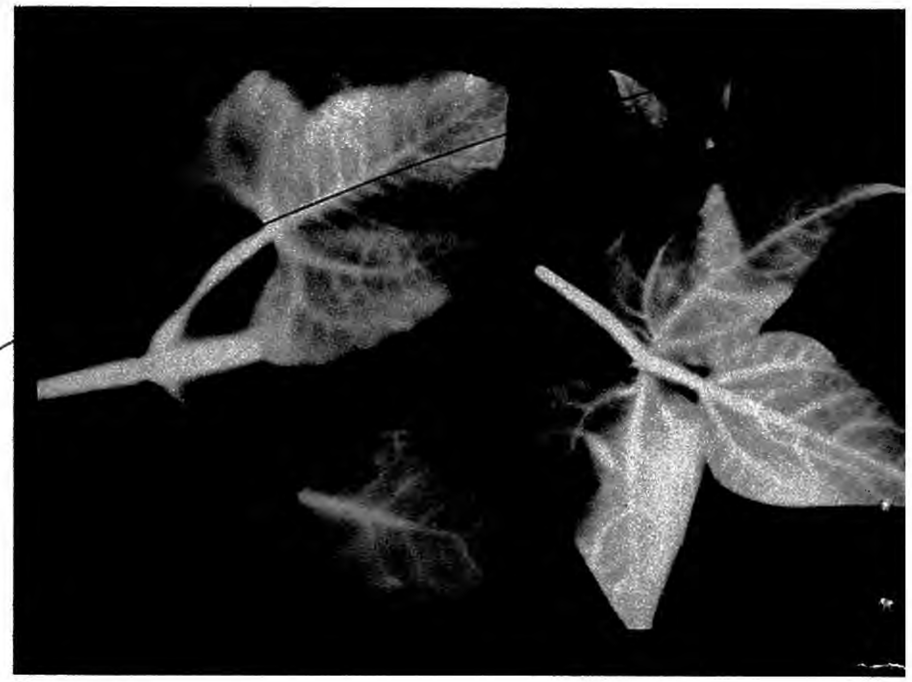
Electromagnetic separation was the other mass-production process chosen. It also depended on well-known principles. In a uniform magnetic field, positive ions will travel in a circle provided they all enter the field with the same velocity and all have the same mass. If the mass is different, the radius of the circle will be different; in fact, the radius of the circle is directly proportional to the mass of the particle. This provides a better separation factor than the gaseous-diffusion process, in which the effect is proportional to the square root of the mass.

Building up to the bomb At Los Alamos, lumps of enriched U-235 were embedded in another lattice or pile, using a hydrogenous moderator, to begin tests for an uncontrolled chain reaction—or explosion. The pile was torn down and rebuilt many times, using less and less moderator, bringing the U-235 lumps closer and closer. Instruments measured the reactions. Finally, after calculations had projected the critical size needed, all lumps—save one—were brought to-

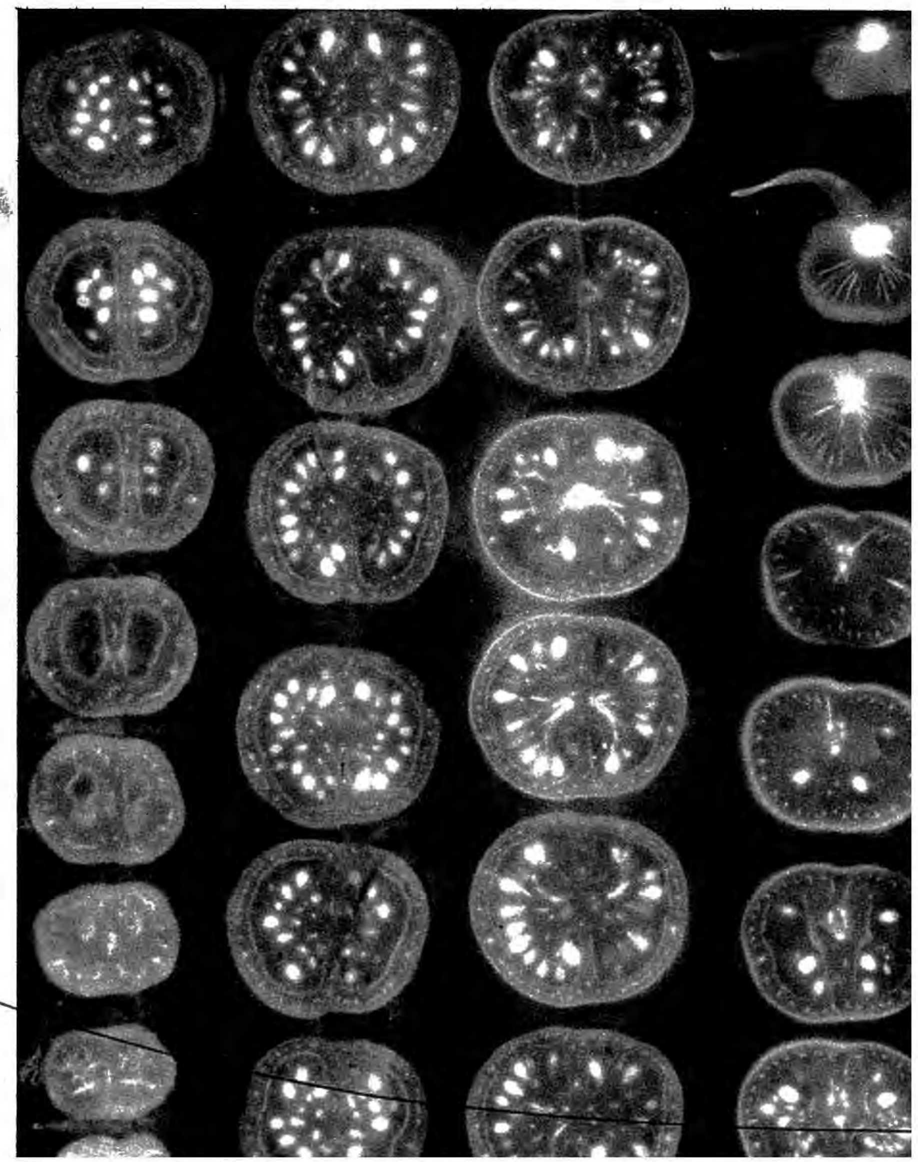


Armed with the idea of an electromagnetic separator, Ernest O. Lawrence, inventor of the cyclotron, and his group at the University of California shot a beam of ions into a large vacuum tank placed between the poles of a magnet. As soon as the ions entered the magnetic field, their path was curved into a semicircle. A catcher was placed at the other end of the tank, its spacing carefully arranged so that it would collect only U-235 ions and not the heavier ones. The major problems, concerned primarily with the production of an intense beam of ions, were finally solved, and on December 6, 1941, Lawrence reported that he could deposit one microgram of relatively pure U-235 in one hour.

Acting on these results, and the substantiation of further research, General Groves in November, 1942, authorized construction of a production plant at the Clinton Engineer Works. Twelve months later the first series of electromagnetic separators was ready for operation. For nearly a year following it was the only plant in production. Now Niels Bohr has stated, in a recent interview in Copenhagen, that the U.S. is producing a total of three kilograms of U-235 a day. In four years we have achieved an increase in production almost one billion-fold.



THE BOMB IS A BYPRODUCT OF PREWAR RESEARCH



THE MAD VENTURE IN PLUTONIUM

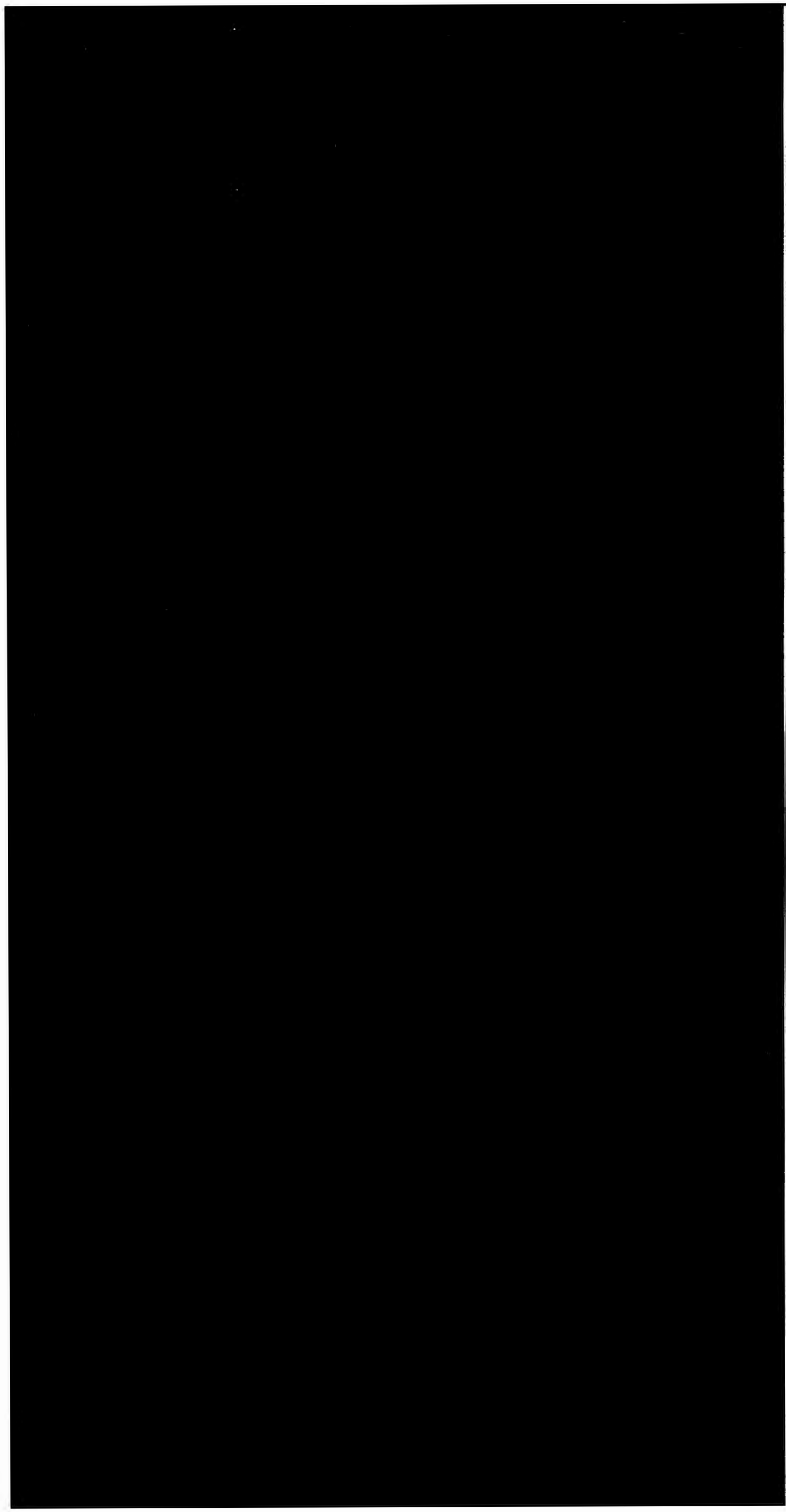
To a physicist, the production of U-235 is dwarfed by the true story of plutonium production. On the face of it, no madder venture has ever been coldly planned by scientists of a civilized nation. A bald statement of facts is staggering. Plutonium was an element unknown in a natural state on earth. By the end of 1942, we had manufactured in this country 500 millionths of a gram of it. Thereupon, in January of 1943, we decided to go into production, and started to build a plant with an output on the order of one billion watts to produce about 1,000 grams of plutonium a day. As if to make the problem more interesting, any such plant would give off radiations in the course of the creation and processing of plutonium that would be of a magnitude hitherto unknown. Those were the bare bones of the problem.

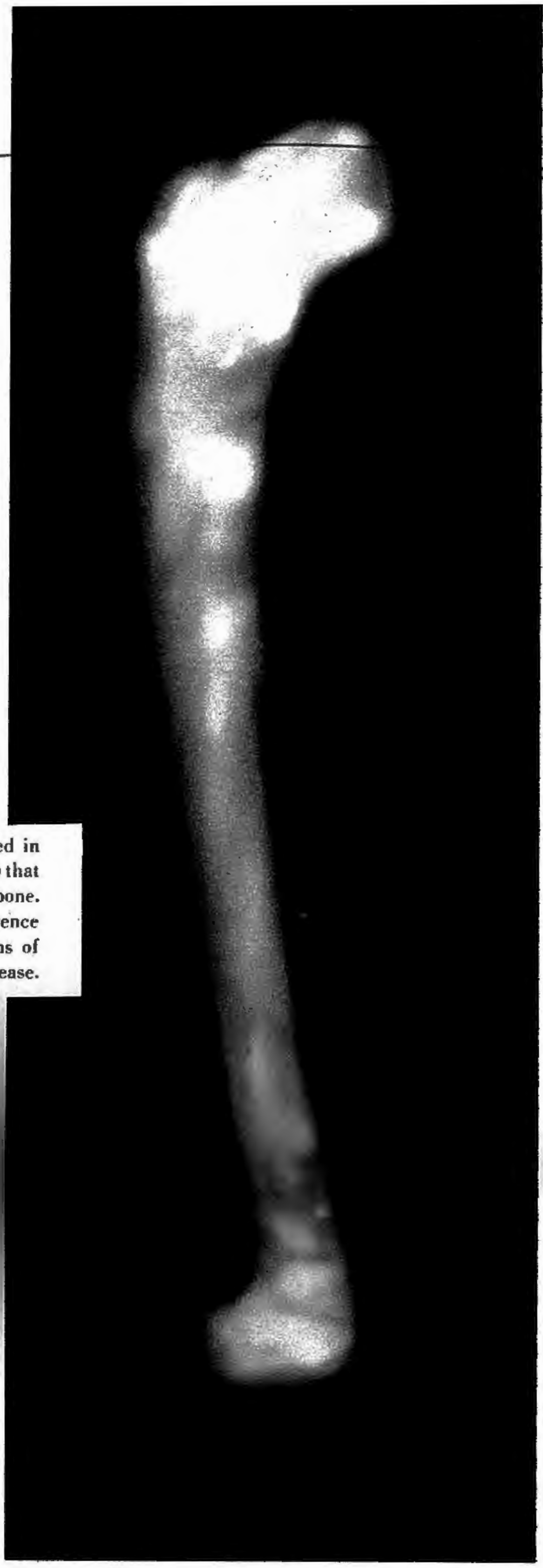
$E = mc^2$

Good ideas often occur in many places simultaneously. A number of scientists independently suggested the production of plutonium in piles. Some of the vast number of neutrons that are available in a pile would surely be captured by U-238 to form U-239. By natural processes this isotope would decay into plutonium. The advantage of getting plutonium, against the process of extracting U-235, was that this new element could be separated from uranium by normal chemical means. The nucleus of plutonium-239 is very similar to that of U-235, and on theoretical grounds it was expected to be even more easily fissionable than U-235.*

With the decision to go into large-scale production came

**The theoretical grounds are complex but interesting. The theoretical reasons why plutonium should be more easily fissionable depend upon two basic factors in fission. Liability to fission is governed by the ratio of the square of the atomic number to isotopic weight—which means, in general terms, that you must have an atom of high atomic weight with a high ratio of protons to neutrons for fission to take place. In addition, the heavy atom must have an odd number of neutrons so that a bombarding neutron pairs with*





Radioactive Carbon,

fed to plants to study how green leaves use solar energy to make organic compounds out of carbon dioxide and water (photosynthesis). Radioactivity takes its own picture (left), puts in a tracer element for chemical analysis. This radioactive byproduct of nuclear research, just before the war, overturned previous ideas as to how photosynthesis works. Solution of this old problem would rival atomic energy.

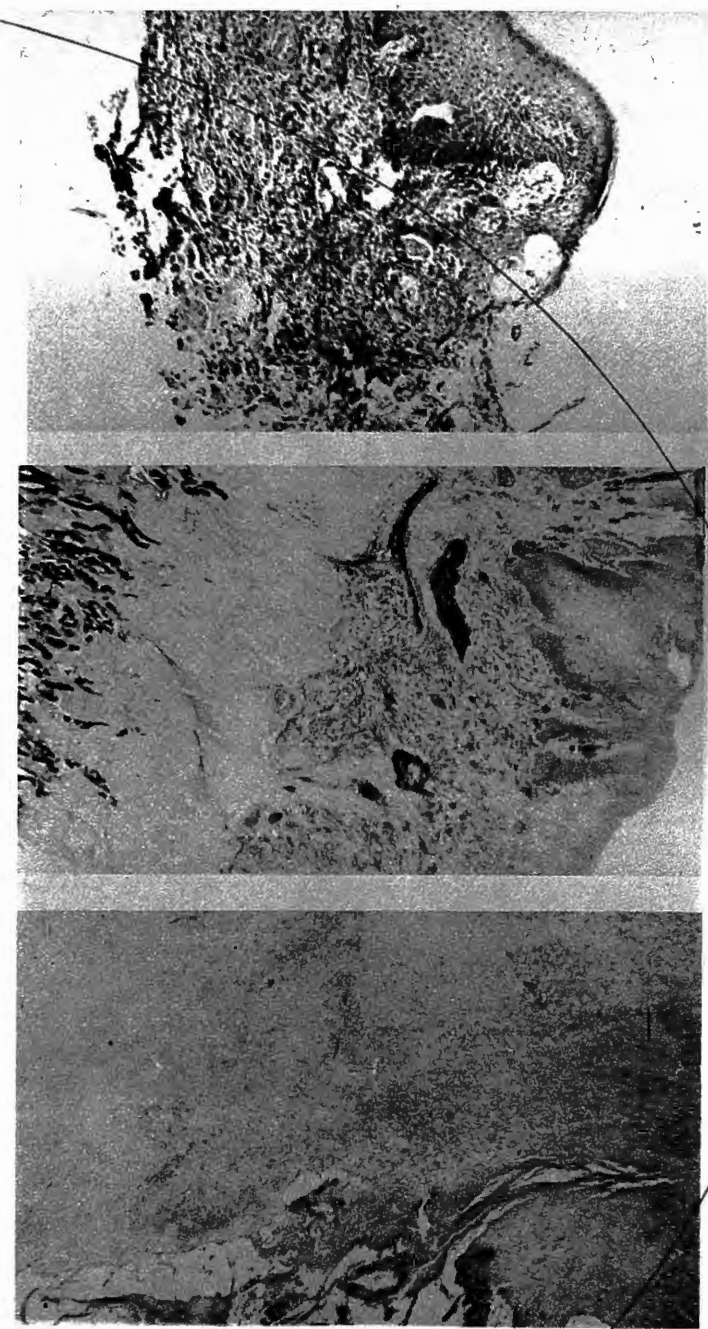
Radiophosphorus,

fed to mice and rabbits, showed in glowing radioautographs (right) that phosphorus is deposited in bone. This gave Prof. John H. Lawrence the idea of feeding it to victims of leukemia, that fatal blood disease.

Leukemia is caused by excess production of white blood cells in bone marrow. Radioactivity kills at the source. Two prewar years of work showed promise, but not yet a cure.

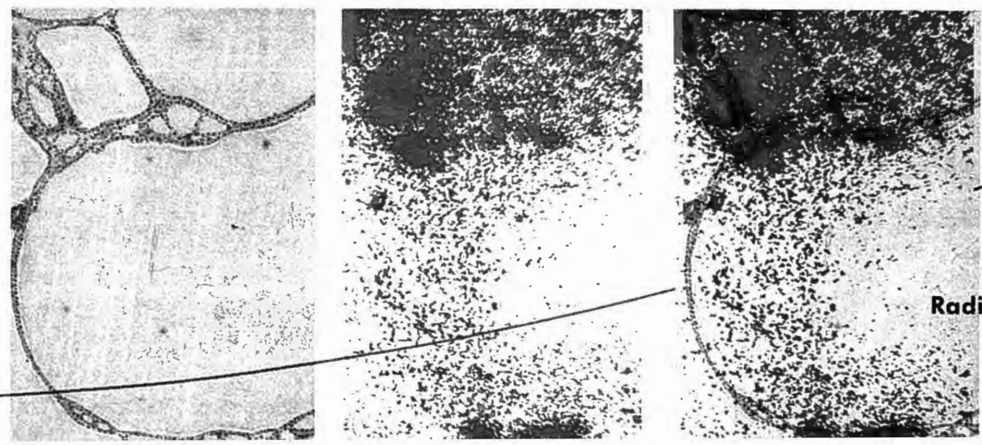
Radioactive Zinc,

fed to tomato plants by Prof. D. R. Hoagland, shows how such radioactive tracers, byproducts of the cyclotron, were putting the study of plant nutrition on the path of new discoveries before the war. Zinc is barely present in tomatoes, yet radioactivity makes them scintillate like fruit of another world.



Neutron Bombardment Kills Cancer

Just before the war, Prof. R. S. Stone of the University of California set out to study the killing effects of direct neutron bombardment of cancer. Neutron beams, directly from the cyclotron, were found more destructive of tissue than X-rays. Early clinical work indicated that controlled beams were particularly effective against some stubborn types of cancer. Above is an example of neutron therapy: (top) cancer of the mouth before treatment; (center) four months after, pale band is dead tissue but both mucous membrane and cancer have regrown; (bottom) seven months after, surface ulceration but no cancer. As in early X-ray therapy, ulcerations difficult to heal and scarring are aftermaths. Much more research is urgently needed, after the interruptions of war. But over-worked cyclotrons aren't up to it, for, in addition to all of their primary use in nuclear research, they are turning out small quantities of all radioactive elements mentioned here, and more. These materials could come in enormous quantities as byproducts from the atomic-bomb production piles, if they are released without unending military delays. The bomb can enormously speed up all of this research, if its byproducts are freed to do it.



Radioactive Iodine in the Thyroid

Drs. Joseph Hamilton and Mayo Soley have devised an ingenious technique in basic studies of the iodine uptake of the thyroid—a major gland in controlling body health. Left to right: a microphoto of abnormal thyroid

many new problems. Uranium could no longer be imbedded in static lumps in the pile, as at Chicago; it had to flow through the pile as the neutrons worked to produce plutonium. New material had to be fed into the pile as the processed uranium was taken away for chemical separation. Dissipation of one billion watts required a magnificent cooling system. Both conditions, material flow and heat dissipation, could be satisfied with an arrangement in which tubes filled with uranium passed right through the lattice. With suitable isolation and protection of the uranium, the cooling material could be pumped through these same tubes. New material could be inserted in one end of the tube and the processed material pushed out the other. After much further research this new lattice arrangement was shown to be satisfactory for a working plutonium pile.

Originally, the Clinton Engineer Works had been chosen as the site for the work. But upon reconsideration of the problems and dangers, General Groves decided that Clinton was not isolated enough. A new site, known as the Hanford Engineer Works, was chosen at Hanford, Washington, on the Columbia River near the power of Grand Coulee Dam.

The Columbia River, "the finest supply of pure cold river water in this country," provided the cooling. Water was pumped through the piles in aluminum tubes—aluminum, because it absorbs neutrons with difficulty. Since uranium reacts with water, uranium slugs had to be sealed in cans. The cans, also made of aluminum, were required to transmit the great heat of the process to the water flowing by. At the same time the cans had to keep the gaseous and other fission products from getting out. The problem of "canning," which was the crux of the operation, was not satisfactorily solved until the last moment.

Chemical separation of plutonium from the uranium was another difficulty because the processed uranium contained only about one-tenth of 1 per cent of plutonium—a figure only one-seventh as large as the content of U-235 in uranium ores. In addition, when the slug emerges from the pile, it is contaminated by a large assortment of fission products, whose elimination is not easy. The method finally used relied on cycles of precipitation, dissolution, oxidation, reduction, and further precipitation.

But over all these processes hung the dreadful pall of radiation. With no radiation, the job to be done was difficult enough; with radiation it took on epic proportions. Piles of this magnitude give off radiation infinitely greater than anything experienced before. At Hanford it was first necessary to protect the personnel from hazards. Periodic checks of white-blood count became routine. Much research was carried out on the effects of radiation. Tolerances were established; instruments were invented to measure whether the tolerable radioactivity was exceeded. These included "Sneezy," which measured the radioactive dust concentration in the air, and "Pluto," which measured contamination of desks and equipment. Geiger counters were used at the exit gates to sound an alarm when anyone contaminated passed through the gates.

Other difficulties arose when the "hot" uranium slugs were taken from the pile for chemical processing. The slugs were transported underwater to a series of concrete cells almost completely buried in the ground. When the uranium was first dissolved, myriads of fission products, all intensely radioactive, were freed. Tall stacks were built to carry off the radioactive gases and discharge them high in the air. And the whole complex of processes—dissolution, precipitation, oxidation, reduction—very properties of matter. No one could confirm experimentally the effect of radiation on the materials comprising the pile. Experience has now shown that the electric resistance, the elasticity, and the heat conductivity of the graphite in the piles all change with exposure to such intense neutron radiation. The whole pile was enclosed in heavy concrete walls made airtight to avoid inducing radioactivity in the very air. Men could work with their hands, building the pile, testing the controls, making all the final adjustments, with no danger to health at all. But once the pile began to operate, no human could approach without fatal effects.

LEADING UP TO THE BIG EXPLOSION

Slow neutrons served best for a controlled reaction, as in the gigantic piles for the production of plutonium. But for an explosive reaction, the minute fraction of a second taken to slow the neutrons down was too long. Fast neutrons were required, even though less efficient. Further research was necessary to determine the critical size for a fast-neutron bomb. To bring off the explosions at a predetermined time was perhaps the most difficult of all the problems remaining.

From time to time between 1942 and 1944 many physicists had disappeared from their previous wartime pursuits to take up residence in an unknown spot. That spot was Los Alamos, situated on a New Mexican mesa, thirty miles from Santa Fe. From its beginning the Los Alamos laboratory was directed by J. Robert Oppenheimer of the University of California. Oppenheimer had been a theoretical physicist with a brilliant, inquiring mind. However, the mind that could solve problems in theoretical physics soon reoriented itself, and Oppenheimer dealt easily with the trying administration, as well as manifold technical problems, of a laboratory set up expressly to create an atomic bomb.

By 1944 a great many keen physicists, foreign as well as American, had been imported to Los Alamos by Oppenheimer. All during the early period of work in this country, the British had also been busy in England and Canada. The original impetus to undertake the project had been strengthened and confirmed by British advice and counsel from the earliest days. At Los Alamos, a British delegation headed by Sir James Chadwick made many contributions to the success of the laboratory. Niels Bohr, after a desperate escape from Denmark, spent much time there assisting in the work.

Since the atomic bomb depended on fast neutrons, experimental verification of the results in fast-neutron fission was needed. One such set of experiments is described in the official report. A pile was built containing a mixture of uranium and a hydrogen moderator. It is not stated explicitly that uranium containing a higher than normal amount of U-235 was used; but certainly many experiments using enriched materials must have been carried out. In its original form, the pile contained enough moderator to be a slow-neutron reacting pile. After the first results were obtained, it was torn down and rebuilt with less moderator. More results were obtained, and the pile was again rebuilt, containing still less moderator. This process, as it went on, approached more and more closely the conditions to be found in a bomb, when in the absence of moderators the fast-neutron reaction would predominate.

For the atomic bomb, as for the pile, there is a critical size below which the number of neutrons escaping from the material is so great that there will be no sustained reaction,

The Physics of the Bomb

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was to keep the critical size small. A further device to aid in this direction is a tamper, a nonabsorbent envelope surrounding the bomb, which reflects the neutrons back into it.

To bring about the greatest explosion, the bomb must be held together as long as possible so that the nuclear reaction will have worked on the maximum amount of material. Once the bomb has begun to disintegrate, the reaction will stop because the neutron density will become too low. So in an effective bomb there is the double problem of providing enough neutrons to make the bomb explode and of holding the bomb together as long as possible to make the explosion as violent as possible. The tamper aids in this last because, in addition to reflecting neutrons back into the bomb, its own inertia makes it harder for the bomb to blow up.

The very nature of critical size imposes a peculiar limitation on the experiments that are possible. Normal explosives can be tested in small quantities. Not so the nuclear explosion, for it must be tested with amounts exceeding the critical size, or not at all. This imposes a heavy responsibility on the theoretical calculations in bomb research. A large group of theoretical physicists had been established at Los Alamos. As they gained experience, methods were devised to obtain closer and closer approximation to the true answer, until accurate calculation gave the critical size and much other important data.

But the major problem was detonation. The bomb had to be transported in fragments smaller than critical size, for once critical size was reached there were plenty of stray neutrons to bring about unpremeditated detonation. A large-caliber gun was proposed to shoot one part of the bomb into the other for detonative assembly. Such a novel projectile would have to travel at high speed along an accurate trajectory to provide perfect contact. For, should the bomb detonate before assembly was completed, it might go off with a fraction of the calculated energy released. Should it fail to detonate, we might present the enemy with our greatest secret, complete with a supply of the necessary material to help him in his experiment. The complexity of the problem can be gauged from the fact that three of the seven experimental divisions at Los Alamos were concerned with detonative and explosive problems.

THE GREAT BALL OF FIRE

Finally, on July 16, 1945, came the test that crowned the long years of calculation, experiment, and manufacture. Careful though the work had been, checked and counterchecked by repeated tests, the final result was always in doubt. The scientists and technicians at work on the bomb at a remote and isolated spot on Alamogordo Air Base must have been tense with excitement. All through the night final arrangements were being completed, and everywhere the tension grew. The description by William L. Laurence of the New York *Times* is melodramatic but still the best.

"Silence reigned over the desert . . . From the east came the first faint signs of dawn.

"And just at that instant there rose from the bowels of the earth a light not of this world, the light of many suns in one.

"It was a sunrise such as the world had never seen, a great green supersun climbing in a fraction of a second to a height of more than 8,000 feet, rising ever higher until it touched the clouds, lighting up earth and sky all around with a dazzling luminosity.

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orange, expanding, growing bigger, rising as it was expanding, an elemental force freed from its bonds after being chained for billions of years.

"For a fleeting instant the color was unearthly green, such as one sees only in the corona of the sun during a total eclipse.

"It was as though the earth had opened and the skies had split."

"THE LONGHAIRS HAVE LOST CONTROL"

With achievement came relief. The work was done—the bomb was proved. But this first climax was not the end; it was a beginning. There is a story that goes the rounds. One of the high military officials watching the experiment grew tenser and tenser as the moment drew near. Stirred by the terrible fury of the explosion he burst out, "My God, the longhairs have lost control." And so we physicists have. Not precisely in the way he feared, but in a way equally terrible.

It must be clear from this article that the atomic bomb is no secret. It obeys the fundamental laws of nature. The exact details of its composition, operation, and detonation are still military secrets. But these are technological details that will yield to persistence and imagination. The great question was—would the bomb work? We have demonstrated the answer to all the world. With this knowledge, these results can be duplicated in a few years, at far less cost, by any capable group of scientists throughout the world.

Having demonstrated this fact, the physicists have indeed lost control. A few years hence, a nation, any willful nation, can destroy our major cities in a few hours. For this we have no remedy. We may indeed be able to destroy their cities afterward, but the whole basis of our communications and our economy—that is, the heart of our ability to make war—will have been wrecked. We have proved the atomic bomb and, in

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so doing, we have placed ourselves at the mercy of the world.

The implications of this fact are clear. Beyond all else, this country must strive to establish a peaceful concourse of nations. This fact transcends all worry about our national economy and prosperity.

Certain subsidiary facts appear. As a military necessity this nation has taken steps to acquire control of all American uranium deposits. If, as now seems likely, useful power can be developed from nuclear disintegration, this government will have perforce nationalized a major source of power. This is but one example of the intricate intermingling of this new destructive power with necessary social action. Throughout all the results that stem from these new discoveries, the same intermixture will be found.

This article is no place for predictions on the possible future uses of this new source of energy. The applications of new power supplies lie in the province of engineering, not physics. From physics we can learn that the size of the piles and the necessity of heavy shields against radiation make nuclear power for airplanes and automobiles impractical at this time. We can also deduce that since other elements besides uranium are fissionable, these may in the future serve as a further source of nuclear power. Much work probably remains to be done, but it seems apparent that nuclear energy will become available at least on a powerhouse scale.

One byproduct of the pile will be production of radioactive isotopes on a scale hitherto unknown. Immediately the prospects of their use in biological research and in medicinal healing will be vastly enhanced. New physical tools will probably become available, and as further information is released, the whole field of nuclear physics can be expected to respond to this new stimulus.

Still it is by no means clear that the vast amount of nuclear knowledge that has been assembled in the course of these projects will be published and made available to physicists. It is unfortunately not even clear that we shall retain freedom of research in investigating the basic nature of matter. Certainly no better method could be found to stultify progress, both scientific and technological, in this country than to retard research. Free, unhampered scientific research, supported by the government, by industry, by universities, is a fundamental necessity. The atomic bomb and the prospects of atomic power are but milestones along the way. Atom smashing has uncovered one secret in the nucleus. Infinitely more remains to be uncovered before we can truly understand the nature of matter. To achieve this end, further free research is the only key.

Credits:

Page 114—Drawing: Matthew Leibowitz; photograph of sun's corona by J. F. Chappell, Lick Observatory, University of California

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Page 120—Official U.S. Army; Hansel Mieth—*Life*; courtesy Dr. J. H. Hoagland, University of California

Page 121—From *Molecular Films: the Cyclotron and the New Biology* by Hugh Stott Taylor, Ernest O. Lawrence, and Irving Langmuir, Rutgers University Press; courtesy Dr. R. S. Stone, University of California (3 photos right); from "Deposition of Radioactive Iodine in Human Thyroid

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Look
VOLUME 14, NUMBER 6
MARCH 14, 1950

How F.D.R. planned to use the A-BOMB

Here, for the first time, a secret wartime adviser reveals that President Roosevelt planned a "warning" demonstration to show the world what the bomb could do—and shock our enemies into surrender

THIS ARTICLE ANSWERS ALL THESE QUESTIONS:

- How did a secret memorandum influence a vital A-bomb decision?
- What story about Napoleon influenced F.D.R. to commit the U. S. to the bomb?
- Why did the President listen to Alexander Sachs?
- What nations would have witnessed a test of the atom bomb's destructive power?
- Did F.D.R., in his last months, change his mind about how to deal with Russia?

By NAT S. FINNEY LOOK WASHINGTON BUREAU

WHAT did President Roosevelt intend to do with the atomic bomb?

It is a strange fact that the biographies and memoirs of Roosevelt's official associates supply no answer to this question.

Dr. Alexander Sachs, recognized in the famous Smyth report as the man who persuaded Roosevelt to launch the atomic-energy project, has now come forward with an answer.

The President, he says, planned to demonstrate the bomb before international representatives of governments, science and religion, before he ordered it dropped on America's wartime enemies.

Dr. Sachs, a New York economist and student of the history of science, bases his assertions about what was in F.D.R.'s mind when he died on conversations he had with Roosevelt as late as December, 1944.

A memorandum advocating a new political strategy to bring about the surrender of Japan without the long, to-the-last-man struggle foreseen by the War Department General Staff was read by him to President Roosevelt immediately before the 1944 elections, Dr. Sachs says. F.D.R. expressed agreement with the ideas contained in the memorandum, and told Major General Edwin (Pa) Watson, his aide, about his views. This memorandum contained an idea Dr. Sachs submitted in a letter of May 8, 1944, which the President acknowledged by a letter to Dr. Sachs. In this May, 1944, letter it was urged that "victory over Germany would accelerate the defeat of Japan" far earlier than the military believed.

A Plan to End the War with Japan

"Final Phase European War and Emerging Opportunity for Liquidating Far Eastern War," was the title of this memorandum. It refers to the atomic bomb only in the code words "exponential weapon." But the meat of the policy it put forward was that with use of the atomic bomb in a series of dramatic warnings, Japan's Ruling House, along with groups that could point to a record of resistance to the Japanese militarists, could regain control of Japan. And that, in view of the utter hopelessness of the outlook of Japan from the spring of 1945 on (with Germany defeated) the Japanese Emperor would accept surrender terms. These terms, Dr. Sachs says, aimed at a "constructive use of the institution of the Emperor, with safeguards."

The memorandum in which Dr. Sachs says he stated the detailed plan for use of the bomb was separate from the one analyzing the opportunity for ending the Far Eastern war. Roosevelt told Dr. Sachs to leave his copy of this separate memorandum with him, and to destroy other copies.

Dr. Sachs says the broad plan, in which use of the bomb was an integral part, had been set in motion before Roosevelt's death at Warm Springs, Ga., in April, 1945. James V. Forrestal, then Secretary of the Navy, had recalled Captain (now Admiral) Ellis M. Zacharias from the West Coast to prepare the series of broadcasts in Japanese that played their part in Japan's ultimate surrender.

Editor's Note—Henry L. Stimson, Secretary of War in 1945, has described the War Department General Staff's estimate of the Far Eastern war situation in July, 1945 in a way that pictures the alternative to Dr. Sachs'

(Continued on next page)

How F.D.R. planned to use the A-BOMB

Adviser says F.D.R. planned expert commission to draft new policy toward an expanding Russia

suggestions for ending hostilities: "The strategic plans of our armed forces for the defeat of Japan, as they stood in July, had been prepared without reliance upon the atomic bomb. . . . We were planning an intensified sea and air blockade, and greatly intensified strategic air bombing, through the summer and early fall, to be followed on November 1 by an invasion of the southern island of Kyushu. This would be followed in turn by an invasion of the main island of Honshu in the spring of 1946. The total U. S. military and naval force involved in this grand design was of the order of 5,000,000 men; if all those indirectly concerned are included, it was larger still. We estimated that if we should be forced to carry this plan to its conclusion, the major fighting would not end until the latter part of 1946, at the earliest. I was informed that such operations might be expected to cost over a million casualties to American forces alone. Additional large losses might be expected among our allies and, of course, if our campaign were successful and if we could judge by previous experience, enemy casualties would be much larger than our own."

A sidelight of Dr. Sachs' story, not directly related to the atomic bomb, is that he urged Roosevelt to revise America's wartime policy toward Russia. Sachs says that at the time he died, Roosevelt was considering appointing a three-man "Colonel House commission" to draft a new Russian policy based on the Kremlin's apparent intention to seize control of Europe.

The relationship between Dr. Sachs and President Roosevelt was known to close mutual friends. But the extent of Dr. Sachs' activities as a personal, nonofficial adviser on atomic energy and grand strategy is little-documented, except in Dr. Sachs' own files. The President's executive officer on some matters of atomic energy was General Watson. Forrestal, who Dr. Sachs says returned from the Pacific in a state of emotional shock that impelled him to reach for any honorable way to end the war, was intermediary with Zacharias. Roosevelt, Watson and Forrestal are dead.

Now It Can Be Told

Dr. Sachs' lips were sealed by a pledge of secrecy to Roosevelt himself. He did not feel himself released until the Smyth report disclosed how he labored to persuade F.D.R. to undertake the atomic energy project, and even then he felt doubt about describing his association with the project during late phases of the war. He has discussed this association with acquaintances in conversations and letters, but the public has not heard the story.

I have examined Dr. Sachs' records of his conversations, and copies of the memoranda he used as the bases of his discussions with President Roosevelt. Here is Dr. Sachs' version of the last chapter of President Roosevelt's life:

Its roots go 12 years deep in time, back to 1932 when F.D.R. was still governor of New York and campaigning against Herbert Hoover for the Presidency. Dr. Sachs, then, and up to the war, with Lehman Corp., and since an independent consultant and director of Lehman Corp., had won himself a reputation in England and the United States as an economist of unusually deep grasp of monetary matters. Through mutual friends, Roosevelt asked Sachs' advice on a projected campaign speech on the gold standard. Sachs tells how he responded with a suggestion that, instead of making a derivative speech, the subject be assigned to the late Senator Carter Glass, who was a master in his own right. F.D.R. heeded Dr. Sachs' counsel, and appreciated the refreshing candor with which it had been given. Thus began as unusual an association of two men as American history records.

Reviewing Our Russian Policy

Its culmination came in February of 1945, just before the failing President left Washington for Warm Springs. In the course of a long, relaxed conversation at the White House, President Roosevelt accepted a view of world events Dr. Sachs says he first put forward in April of 1943—the view that American policy could not be based upon expectation of a friendly and co-operative Soviet Union. The President undertook to reconsider the philosophy underlying his administration's expectation of a postwar era of one-worldism, and to take under serious advisement the revision of the policy he theretofore had followed.

He agreed, says Dr. Sachs, with the contention that the ordinary state and military agencies of the Federal Government were so fixed in the patterns of the old policy that they could not hope to develop a new one. They suffered, Dr. Sachs explains in his own phrases, from hardening of the categories, blinkered thinking, encrusted ideas. Roosevelt planned to name Lewis Douglas, Dr. Sachs and one other man, not designated when F.D.R. died, to a special Presidential commission that would make a fresh review of the facts and present fresh conclusions so forcibly as to command the change F.D.R. might seek.

Plans for using the bomb had an earlier culmination. This occurred after the 1944 elections, during the first week of December to Dr. Sachs' recollection. Roosevelt and Sachs met at the White House where Sachs says he read what is here called his lost memorandum. At the conclusion of the two men's long conversation, the President nodded his agreement to Dr. Sachs' proposals for the use of the atomic bomb.

"For God's sake tell someone," Sachs pleaded.

The President agreed to "tell Pa," (General Watson). Dr. Sachs is satisfied that General Watson was told. His plea to President Roosevelt that someone be told was prompted by his own observation that F.D.R.'s powers were overstrained, and his anxiety that he, who had been insistent upon holding no official position whatever, might not be sole possessor of such a secret. The President, in Dr. Sachs' poignant phrase (he thinks it comes from Shakespeare but cannot find the line) was becoming "yonderly minded." Lengthening pauses spaced F.D.R.'s conversations with Dr. Sachs, pauses during which the President was there, yet in a sense not there. The line and coherence of F.D.R.'s thought was not broken by these pauses, which Dr. Sachs respected in silence, but the continuity of the President's on-pressing drive was momentarily suspended as if he listened inwardly to another, private harmony.

Our Enemies Would Be Warned

Here, as recaptured later by Dr. Sachs in a letter to Secretary of War Robert P. Patterson, is the proposal for the atomic bomb's use with which F.D.R. expressed agreement in December, 1944:

"Following a successful test, there should be arranged (a) a rehearsal demonstration before a body including internationally recognized scientists from all Allied countries and, in addition, neutral countries, supplemented by representatives of the major (religious) faiths; (b) that a report on the nature and the portent of the atomic weapon be prepared by the scientists and other representative figures; (c) that, thereafter, a warning be issued by the United States and its allies in the Project to our major enemies in the war, Germany and Japan, that atomic bombing would be applied to a selected area within a designated time limit for the evacuation of human and animal life, and, finally (d) in the wake of such realization of the efficacy of atomic bombing, an ultimatum demand for immediate surrender by the enemies be issued, in the certainty that failure to comply would subject their countries and peoples to atomic annihilation."

(Dr. Sachs' recommendation that representatives of the major religious faiths attend the atomic-bomb demonstration called for something more than Catholics, Protestants. . . . He wanted representatives of Judaism, Mohammedanism and Buddhism.)

Facts Have Been Twisted

This was the understanding in early December of 1944, and so far as Dr. Sachs can recollect or was informed, it remained the understanding until President Roosevelt's death on April 12, 1945. Yet a simple restatement of the plan as put down by Dr. Sachs in July, 1946, from his memory of the memorandum, can lead to profound misunderstanding of what was in the minds of Dr. Sachs and President Roosevelt when they last discussed their shared secret of the vast atomic project that was then approaching fruition. Indeed, incomplete information about the plan on which the minds of Dr. Sachs and Franklin Roosevelt then met has already been tortured and twisted to make it appear that had Roosevelt lived Hiroshima and Nagasaki would never have occurred. (Editor's Note—This is not, as might appear to some, a denial that F.D.R had *planned* to demonstrate the bomb before using it as a military weapon. Dr. Sachs is simply making it clear that neither he nor anyone else can be sure of what F.D.R. might have done had he lived to face the situation existing in August, 1945. The Roosevelt plans called for more atomic bombs than actually existed in August, 1945. Obviously, Dr. Sachs

Dr. Alexander Sachs

To close friends who know the quality of Dr. Alexander Sachs' mind only one word adequately describes him. The word is genius. A story about how he helped President Roosevelt to understand the atomic energy problem in 1939 throws light on why Dr. Sachs is so described. It shows how he thinks.

F.D.R. was worried whether an atomic weapon could be ready in time to decide the outcome of the war. Dr. Sachs had estimated the project might cost two billions, and honestly told the President that, ordinarily, it would take 25 years to do the job. He explained to F.D.R. that he had searched the history of human thought for an example of how time could be telescoped.

He found the example in music, he says. The composer of music has ways of making time three-layered. Remember the old round you used to sing:—"Are you sleeping, etc?" Three tunes going at once, harmoniously overlapping each other. This, he advised, was what must be done with the atomic project:

"When you start one part of the project, assume you have finished it successfully, and start the next as if you had." That is exactly what was done, probably for the first time with such a huge undertaking. It worked.

This man who makes a lifework of thinking in such unusual patterns was born 56 years ago at Rossien in Czarist Russia. He came to the United States in 1904. He was schooled at Columbia University and Harvard, but has never left the school of self-education.

Dr. Alexander Sachs' career has been in economics, with special emphasis on the mathematics of statistics. But the range of his intellectual interests embraces religion, science, history and politics. America is his home but he is well-connected in England and on the Continent.

Dr. Sachs was a special consultant to Gen. William J. Donovan, chief of the Office of Strategic Services, and economic adviser to the Petroleum Industry War Council during the war. These were his formal jobs. His relations with President Roosevelt were informal, unofficial and, until now, anonymous.

could not know how this and other technical facts might have caused F.D.R. to change his plans.) It has been whispered that President Truman knowingly brushed this plan aside in favor of the actual use of the bomb decided upon by an interim committee headed by Secretary of State James F. Byrnes and Secretary of War Henry Stimson. This committee, Secretary Stimson records, submitted its conclusions to a panel of distinguished scientific advisers who, partly because they could not, in the light of the facts, suggest an alternative, raised no objection to the way in which the bomb was used.

Dr. Sachs emphatically disagrees with those who argue that the American-British-Canadian team of nations that made the bomb is morally guilty for the use made of it. While he continues to believe that the broad sense of his proposal for a demonstration under international, inter-religious auspices of the weapon's powers could have been made when the bomb was tested at Alamogordo, N. M., he is convinced that the essential features of President Roosevelt's plans for using the bomb were actually carried out. Dr. Sachs decries the kind of "apocalyptic thinking" that makes the precise use of the atomic bomb the central overshadowing item in the unfolding of the President's much-more-comprehensive plan to bring about the surrender of Japan through negotiations with Hirohito after our facilitating a political coup d'état.

He points out that there was a warning to Japan—numerous warnings culminating in the ominous Potsdam Declaration. He continues in the belief that, had these warnings been sharply dramatized by such a disclosure of the bomb's awful powers as he conceived, Hirohito might well have been able to regain control earlier. Yet, he emphasizes, it was the bomb's terrific impact that sealed victory in the psychological war President Roosevelt had set in motion by having Captain Zacharias recalled to Washington to speak to Japan in Japanese that forethoughtfully included ceremonial and archaic language to appeal to the court and high naval and other officials. Dr. Sachs has only praise for the responsible men who made the fateful, final decisions in carrying through broad plans that were never seriously questioned by Roosevelt's successors, despite the great unpopularity of all suggestions that a deal should be made with the Japanese emperor.

History Teaches F.D.R.

He has a sharp word for persons who now give currency to an American "guilt complex" at the use of the bomb. He compares this "self-denigration" to the soft-thinking about Germany which followed World War I, and he warns that the upshot could be similar.

His story of the conversation with President Roosevelt, during which a decision was reached on use of the bomb as an integral part of ending the slaughter in the Pacific, suggests that Roosevelt may have been weighing in his mind all the political and moral implications of the use of the bomb. (It must be remembered that in December, 1944, there was no certainty the weapon could be made or would be ready in time to provide a sign or shocking accent to hasten the end of the mounting horror by other weapons of scientific killing.) Dr. Sachs says his way of dealing with President Roosevelt was to prepare a careful memorandum and read it aloud, pausing to discuss any fact or concept that raised a question in F.D.R.'s mind. Sachs would then attempt to support a crucial point by a story drawn from history—Roosevelt was an avid, ranging reader of history with relish for a telling passage, particularly when it was new to him. The discussion on this December day revolved about the subtle point of a stateman's responsibilities to history, and the rightness or wrongness of visiting the world with a new agent of destruction. Dr. Sachs was ready with a story.

You Can't Bury a Discovery

Toward the end of the sixteenth century, John Napier, the Scotsman who invented the logarithmic tables, became greatly interested in engines of war because of his Protestant zeal that Britain should never fall to such a threat as the Spanish Armada. Napier's biographer and descendant, Dr. Sachs told the President, learned that the Scotch mathematician had not only devised such weapons as sets of burning mirrors and primitive tanks, but had come upon an invention which succeeded in annihilating all animal life in an area of a square mile. His biographer, Sachs told President Roosevelt, recounted that Napier was "so disquieted that he buried the machine," feeling that "mankind had many engines with which to destroy each other and that . . . he would never willingly increase them."

With this story as his key, Dr. Sachs says he convinced President Roosevelt that it was neither possible nor desirable to suppress such a discovery as was being brought to birth within the Manhattan District. He saw the bomb as the climax of human technological

(Continued on next page)

How F.D.R. planned to use the A-BOMB

With the support of an Einstein letter and a story, Sachs induced F.D.R. to launch A-bomb project

achievement, linked to the most fundamental forces of nature. Its use would be a readily readable sign to the whole of humanity, and would, therefore, foreshorten the war and save millions of lives of our own and the allies, and our enemies as well. But that the weapon must, at the very least, be demonstrated so that the complexities of its impact upon human development would be felt. This, in its strange and somewhat indirect way, was the crux of the President's decision—a decision with an elaborate background that can be understood only by some grasp of the relationship between F.D.R. and Dr. Sachs, his most unusual confidential adviser.

Sachs Spoke Out

The beginning of this relationship has been described. At their first meeting, President Roosevelt found in Dr. Alexander Sachs an enormously well-informed man who preferred complete anonymity and had no hesitation whatever about differing with the President when he believed him to be in error. Few who knew Roosevelt well can be surprised that he formed an attachment to Dr. Sachs. The attachment grew through the years. It grew for reasons that are clearly on the record. In his own and related fields—modern economics—Dr. Sachs has a startling record of having been right when the pack of more orthodox thinkers was wrong. He foresaw that the National Recovery Administration would be a failure and be held unconstitutional, and very frankly advised F.D.R. of what he anticipated. Yet he back-stopped the late Hugh Johnson through the NRA days. There are numerous other instances of the sort.

One central belief held steadily by Dr. Sachs in the years when World War II was gathering was the key to his peculiar helpfulness to Roosevelt. Sachs demonstrated historically that the Great Depression was something more profound than a collapse in the economic sphere. It was a collapse of the Great Culture of Western Europe. During the 1932 campaign, Dr. Sachs asked F.D.R. whom he considered his principal opponent. "Why, Herbert Hoover, of course," the New Deal candidate replied. "You are wrong, Mr. Roosevelt," Sachs says he told his friend. "Your enemy is Adolf Hitler."

He Saw War Coming

Long before other advisers to F.D.R. warned him that the great threat was aggressive war by the dictators, Dr. Sachs was correctly interpreting events in Europe and Asia. Partly because of his deep feeling of alarm about the oncoming war, Dr. Sachs kept a sharp eye on unfolding events in the scientific world. As the 1930's drew toward their end, a providential combination of circumstances made Dr. Sachs perhaps the only man who could have advised President Roosevelt about atomic energy.

His long record of giving the President sound advice in economic matters caused F.D.R. to rely upon him. His steadfast refusal to accept any public favor or assignment convinced Roosevelt he had discovered a counselor who genuinely desired anonymity. Dr. Sachs' lifelong interest in fundamental science (he is reputedly a first-rate mathematician) caused him to follow and understand the emergent possibility of unlocking the huge energies inside the atom. He attended a series of lectures in England in 1936-37 at which Lord Rutherford and F. W. Aston clearly forecast atomic energy. At the beginning of 1939, he secured one of the few careful translations made of the historic Hahn-Strassmann report on atomic fission.

During the latter phases of the Nazi purge of non-Aryan members of the great German scientific community, Dr. Sachs became interested in helping those who needed to be rescued. He got acquainted with some of these émigré scientists in the course of his professional trips in England. Others came to the United States and Canada. Through them, Dr. Sachs got the most expert, personal advice. Thus, in the summer of 1939, when the Navy Department flatly turned down proposals for an atomic project, Dr. Sachs was being told by such men as Drs. Leo Szilard and Eugene Wigner that the possibility of atomic weapons could not be neglected.

1939: Year of Decision

Dr. Sachs says he undertook to familiarize President Roosevelt both on the scientific possibilities of atomic energy, and the political possibilities if Germany became able to terrorize the democratic world with an atomic devastator. It is hard now to recall what things were like in early 1939. Austria had been swallowed by Hitler in 1938. Czechoslovakia, deserted by shock-sick England and France, had been taken over without a shot. The United States had no means for offensive war. Dr. Sachs says he became F.D.R.'s personal Jeremiah on the subject of technological warfare because of real fear that Germany might succeed in terrorizing the whole world.

During the late summer of 1939, Dr. Sachs says he broached the subject with President Roosevelt about starting an atomic project. The President was so preoccupied with problems of the neutrality act that he could not then give the matter attention. The story of how Dr. Sachs enlisted Dr. Einstein to contribute a supporting letter to the dossier of material he used to convince the President is told in the Smyth report, and Dr. Sachs' testimony before the Congressional atomic energy committee fills in a good deal of detail. But Dr. Sachs has never publicly told the story of the crucial meeting at which President Roosevelt decided to commit himself to making an atomic weapon.

On October 11, 1939, Dr. Sachs read a long letter-memurandum of his own to President Roosevelt along with the letter signed by Dr. Einstein and a joint memorandum signed by Dr. Szilard and himself. The President was impressed and willing tu help, but not convinced he should embark on such a costly course of action under government auspices. (Dr. Sachs later advised him that producing an atomic weapon might well cost two billion dollars on the basis of the telescoped cost of electrical power in the generation before World War I.) Dr. Sachs says he asked President Roosevelt if he could see him the next day. The President invited him to come to breakfast.

Dr. Sachs tells how he spent most of that night either at his room at a Washington hotel, or in nearby Jackson Park trying to think of

President Roosevelt valued the advice of Dr. Alexander Sachs, his least-known aide, on economics and, later, atomic energy.

Military observers view stark, granulated ruins

of Hiroshima, a year after the atom bomb blast. A "warning" demonstration of the bomb's power might have averted the destruction of this city and Nagasaki.

something he might say that would bring the President to order a study of the feasibility of atomic weapons. He recalls returning to his hotel room at dawn, and of dozing in a chair while waiting the operator's wake-up call. He did not go to bed for fear he would lose the thread of what he wished to tell the President.

He came back to the White House, he says, to find Roosevelt seated alone at his breakfast table while a servant attended him. As he sat down, the President said:

"What bright idea have you got now? How much time would you like?"

Dr. Sachs says he replied that he would not take long. "All I want to do is tell you a story." This is Dr. Sachs' recollection of the story.

Lord Acton and the Atom Bomb

He told the President that many years before, while he was in his final year at Columbia University, he had become acquainted with a philosopher and theologian, Prof. Dickinson Sergeant Miller. Later, in 1913, through this friendship, he met and talked to a visiting British divine, the Rev. John Neville Figgis. Father Figgis, he explained to President Roosevelt, had written a book on political theory entitled *From Gerson to Grotius*. This interest in European politics caused Father Figgis to be chosen as literary executor and editor of the lectures and writings of Lord Acton, a famous English political historian with whose work President Roosevelt was acquainted.

Father Figgis, Dr. Sachs told President Roosevelt, discovered that Lord Acton had been asked an unusual question about English history. Could Lord Acton mention an outstanding instance of England being saved from national peril, not by its own efforts, but by the failure of an enemy to seize advantage of an opportunity to destroy England? Dr. Sachs explained that, according to Father Figgis, Lord Acton asked a day to consider the question.

Napoleon Blunders

The next day, Dr. Sachs told President Roosevelt, Lord Acton was ready with his answer. There was an outstanding example of how England had been saved by an enemy's mistake. During the Napoleonic Wars, after Bonaparte had tried to land his armies on England's shores and failed because of the English Channel's tricky tides and currents, a young American inventor came to the French Emperor with an idea.

The inventor was Robert Fulton, and his idea was that Napoleon build a fleet of steamships that could overpower the channel's currents. Then Napoleon would be able to land his armies, and a helpless England would be at his mercy.

Dr. Sachs repeated Lord Acton's story of how Napoleon scoffed at Fulton's idea. And he told President Roosevelt how Lord Acton held that if the French Emperor, then at the zenith of his power, had only had the humility and the imagination to entertain a new idea the nineteenth century history of England might have been far different.

Dr. Sachs says President Roosevelt sat silent when he had finished his story. "That seemed like a very long silence to me," he recalls. "I suppose it was two or three minutes, but it seemed like half an hour." The servant, Dr. Sachs remembers, was clearing away the dishes and, without saying anything, President Roosevelt scribbled something on a piece of note paper and handed it to the servant. A moment later the servant returned with a tall package. When he unwrapped it, Dr. Sachs saw it was a magnum of Napoleon brandy. The servant drew the cork, and not until then did Mr. Roosevelt speak. He ordered the servant to pour.

A Toast to the Future

When each man, President Roosevelt and Dr. Sachs, held a pony of the old brandy, the President clicked his glass with Dr. Sachs and drank. Then, with a friendly gesture, he told Dr. Sachs he would take action on atomic energy. General Watson was directed to follow through.

END